

BACKGROUND

The long-term objective of the U.S. AMLR field research program is to describe the functional relationships between Antarctic krill (*Euphausia superba*), their predators, and key environmental variables. The field program is based on two working hypotheses: (1) krill predators respond to changes in the availability of their food source; and (2) the distribution of krill is affected by both physical and biological aspects of their habitat. To refine these hypotheses a study area was designated in the vicinity of Elephant, Clarence, and King George Islands, and a field camp was established at Seal Island, a small island off the northwest coast of Elephant Island. From 1989-1996, shipboard studies were conducted in the study area to describe variations within and between seasons in the distributions of nekton, zooplankton, phytoplankton, and water zones. Complementary reproductive and foraging studies on breeding pinnipeds and seabirds were also accomplished at Seal Island.

Beginning in the 1996/97 season, the AMLR study area was expanded to include a large area around the South Shetland Islands, and a new field camp was established at Cape Shirreff, Livingston Island (Figure 1). Research at Seal Island was discontinued due to landslide hazards. Shipboard surveys of the pelagic ecosystem in the expanded study area are accomplished each season, as are land-based studies on the reproductive success and feeding ecology of pinnipeds and seabirds at Cape Shirreff. During the 1999/2000 season, the AMLR program also participated in a multi-nation, multi-ship survey of krill throughout the Scotia Sea, known as the CCAMLR 2000 survey.

SUMMARY OF 2000 RESULTS

The Russian R/V *Yuzhmorgeologiya* was chartered to support the U.S. AMLR Program during the 1999/2000 field season. This was the first year of a new 5-year charter with the vessel operators after four successful previous seasons. Shipboard operations included: 1) participation in a multi-nation, multi-ship survey of Antarctic krill across the Scotia Sea; 2) a joint Zodiac/ship inshore survey of krill and oceanographic conditions near Cape Shirreff; 3) a region-wide survey of krill and oceanographic conditions in the vicinity of the South Shetland Islands; 4) calibration of acoustic instrumentation at the beginning and end of survey operations; and 5) shore camp support. Land-based operations at Cape Shirreff included: 1) observations of chinstrap and Adélie penguin breeding colony sizes, foraging locations and depths, diet composition, breeding chronology and success, and fledging weights; 2) instrumentation of adult penguins to determine winter-time migration routes and foraging areas; 3) observations of fur seal pup production and growth rates, adult female attendance behavior, diet composition, foraging locations and depths, and metabolic rates; 4) collection of female fur seal milk samples for determination of fatty acid signatures; 5) collection of fur seal teeth for age determination and other demographic studies; 6) tagging of penguin chicks and fur seal pups for future demographic studies; and 7) establishment of a weather station for continuous recording of meteorological data.

The CCAMLR 2000 Survey was conducted in collaboration with vessels from Japan, Russia and the UK (Figure 2). Sampling protocols, survey design, analysis procedures, and detailed results are presented elsewhere (SC-CAMLR-XVIII, Annex 4, Appendices D and E; SC-CAMLR-XIX, Annex 4, Appendix G). Marine mammal and bird observers from the International Whaling

Commission also participated on the survey. Oceanographic fronts located at the central axis (SACCF) and southern boundary of the Antarctic Circumpolar Current were evident at all major transects across the Scotia Sea. Chlorophyll concentrations were highest north of the SACCF, with lower values south of the SACCF that increased toward the southern boundary. Lowest chlorophyll concentrations and highest krill densities were observed in the vicinity of the South Orkney Islands. Three geographically distinct size clusters of krill were also mapped across the Scotia Sea. Very large krill (52mm modal length) were sampled in the western Scotia Sea and Drake Passage. Another cluster (48mm modal length, but also containing several samples of intermediate size krill) was mapped in the inshore waters adjacent to the Antarctic Peninsula and extended across the northeastern part of the survey area. Small krill (26mm modal length) were found in the eastern portion of the Scotia Sea in a broad tongue extending from the southern part of the survey area between the South Orkney and South Sandwich Islands north to the eastern end of South Georgia. A preliminary examination of the oceanographic data suggested the small krill may have been transported into the Scotia Sea from the Weddell Sea. Similar biogeographic patterns were apparent in salp demographics and macro-zooplankton species composition mapped from samples collected aboard the *Yuzhmorgeologiya* (approximately one-third of the total number of samples). Krill densities (estimated from the combined data sets) were highest over the continental shelves surrounding the South Shetland, South Orkney, South Georgia and South Sandwich archipelagos. Overall krill density was estimated to be 21.3 g/m^2 over a survey area of $2,065 \times 10^3 \text{ km}^2$ for a total biomass of 44.3 million tons (CV 11.4%).

The inshore survey near Cape Shirreff (Figure 3) was accomplished using a 5-m Zodiac configured with a 120kHz echo sounder, an underwater video camera, a CTD, several continuously recording sea surface and meteorological sensors, two GPS receivers, a radar, and emergency equipment. The Zodiac was used to map krill within 15 nautical miles of the Cape while the ship surveyed further offshore. The survey was staged from the field camp and conducted over a 5-day period. Substantial amounts of krill were mapped inshore of the region surveyed by the ship and the feasibility of using a small boat to conduct inshore surveys in Antarctica was demonstrated.

An oceanic frontal zone was mapped along the north side of the South Shetland Islands, running parallel to the continental shelf break and separating Drakes Passage water to the north from Bransfield Strait water to the south (Figure 4). The prevailing flow was southwest to northeast; however, both the front and geostrophic flow lines diverged to the north in the vicinity of Elephant Island. Chlorophyll concentrations were above average and highest south of the frontal zone. Highest densities of krill were mapped between King George, Elephant and Clarence Islands and along the shelf break north of the archipelago. Mean krill biomass density in the Elephant Island area was estimated to be 37.5 g/m^2 , higher than that observed in 1999, and in conformance with a long-term cyclic trend. Sampled krill were predominately large and sexually mature; the few immature krill caught were large and probably post-spawning; and only two out of 2,100 specimens processed were juveniles. Virtually all of the sampled krill represented the 1994/95 and 1995/96 year classes. High densities of late krill larval stages suggest an active and prolonged 1999/2000 spawning season. Demographic analysis of sampled *Salpa thompsoni* suggested the population may have initiated seasonally early production of the over-wintering form. Copepods and larval krill dominated the zooplankton assemblage, although salps were widespread and relatively abundant as well. This, and other aspects of the zooplankton

assemblage, suggested that 1999 and 2000 may be classified as transition years between a salp-dominated community and a copepod-dominated community. Acoustically detected layers of myctophid fish were mapped north of the frontal zone and appeared to be associated with the southern boundary of the ACC.

The numbers of chinstrap and gentoo breeding pairs were higher than the previous season and above the three-year mean for the Cape Shirreff monitoring site. Overall reproductive success for chinstrap penguins was lower than average, but fledging weight was slightly higher than average. Conversely, overall reproductive success for gentoo penguins was higher than average, and fledging weight lower than average. Large krill (41 – 55mm) were present in 100% of the sampled diets from both species, while fish were evident in 3% of chinstrap and 80% of gentoo penguin samples. The distribution of foraging trip durations for chinstrap parents were bimodal. Shorter trips (8-hr mode) were initiated between dawn and noon; longer trips (12-hr mode) began later in the day and included the dark period. The median birth date of fur seal pups was two days earlier and total pup production was 5.8% higher than the previous season. Return rates of adult females were comparable to last year, although the return rate for yearlings was lower. Foraging trip duration for lactating females was significantly less than the last two years. As in previous years, an increase in fish and squid in the diet was observed as the season progressed. Teeth were extracted from 80 fur seals for age determination and other demographic studies; operations proceeded according to approved protocols and no adverse reactions were noted.

References:

SC-CAMLR-XVIII. 1999. CCAMLR Synoptic Planning Meeting. Appendix D to Report of the Working Group on Ecosystem Monitoring and Management. In: *Report of the Eighteenth Meeting of the Scientific Committee* (SC-CAMLR-XVIII), Annex 4. CCAMLR, Hobart, Australia: 191-202.

SC-CAMLR-XVIII. 1999. CCAMLR 2000 Krill Synoptic Survey: A Description of the Rationale and Design. Appendix E to Report of the Working Group on Ecosystem Monitoring and Management. In: *Report of the Eighteenth Meeting of the Scientific Committee* (SC-CAMLR-XVIII), Annex 4. CCAMLR, Hobart, Australia: 203-225.

SC-CAMLR-XIX. 2000. Report of the B₀ Workshop. Appendix G to Report of the Working Group on Ecosystem Monitoring and Management. In: *Report of the Nineteenth Meeting of the Scientific Committee* (SC-CAMLR-XVIII), Annex 4. CCAMLR, Hobart, Australia.

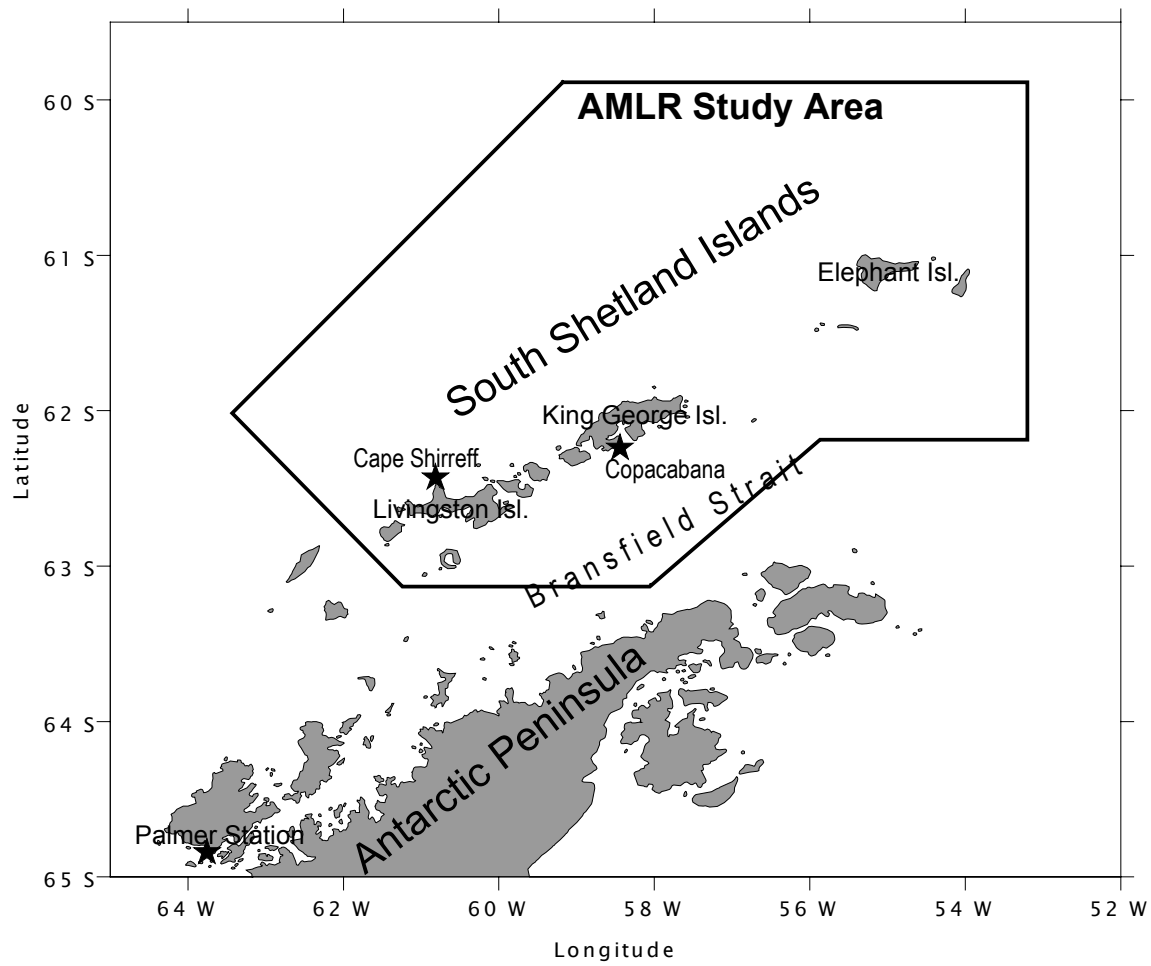


Figure 1. Locations of the U.S. AMLR field research program: AMLR study area, Cape Shirreff and Copacabana.

OBJECTIVES

Shipboard Research:

1. Conduct the portion of the CCAMLR 2000 survey for Antarctic krill in the Scotia Sea that is assigned to the U.S. survey ship (R/V *Yuzhmorgeologiya*).
 2. Conduct a high-resolution survey for krill in the vicinity of Cape Shirreff using a specially-equipped Zodiac for the inshore areas and the *Yuzhmorgeologiya* for the offshore areas.
 3. Calibrate the shipboard acoustic system in Leigh Harbor, South Georgia near the beginning of Leg I, at Cape Shirreff near the beginning of Leg II, and again at Admiralty Bay near the end of Leg II.
- Conduct a survey in the vicinity of the South Shetland Islands during Leg II to map meso-scale features of the dispersion of krill, water mass structure, and zooplankton constituents.
5. Collect continuous measurements of the research ship's position, sea surface temperature, salinity, turbidity, fluorescence, air temperature, barometric pressure, relative humidity, and wind speed and direction.
 6. Provide logistical support to two land-based field sites: Cape Shirreff (Livingston Island), and Copacabana field camp (Admiralty Bay, King George Island).

Land-based Research:

Cape Shirreff

1. Estimate chinstrap and gentoo penguin breeding population size.
 2. Band 1000 chinstrap and 200 gentoo penguin chicks for future demographic studies.
 3. Record at sea foraging locations for chinstrap penguins during their chick-rearing period using ARGOS satellite-linked transmitters (PTTs).
 4. Determine chinstrap and gentoo penguin breeding success.
 5. Determine chinstrap and gentoo penguin chick weights at fledging.
 6. Determine chinstrap and gentoo penguin diet composition, meal size, and krill length/frequency distributions via stomach lavage.
 7. Determine chinstrap and gentoo penguin breeding chronologies.
- Deploy time-depth recorders (TDRs) on chinstrap and gentoo penguins during chick rearing for diving studies.
- Collect data on foraging locations (using PTTs) and foraging depths (using TDRs) of chinstrap penguins while concurrently collecting acoustically derived krill biomass and location data during the inshore survey.
- Deploy PTTs on chinstrap penguins following adult molt to determine migration routes and winter foraging areas in the Scotia Sea region.
- Document Antarctic fur seal pup production for Cape Shirreff and assist Chilean colleagues with censuses of fur seal pups for the entire Cape and the San Telmo Islands.

Monitor female Antarctic fur seal attendance behavior.
Assist Chilean researchers in collecting Antarctic fur seal pup length, girth, and mass for 100 pups every two weeks through the season.
Collect 10 Antarctic fur seal scat samples every week for diet studies.
Collect a milk sample at each female Antarctic fur seal capture for fatty acid signature analysis and diet studies.
Record at-sea foraging locations for female Antarctic fur seals using PTTs.
Deploy TDRs on female Antarctic fur seals for diving studies.
Measure at-sea metabolic rates and foraging energetics of lactating Antarctic fur seals using doubly-labeled water.
Tag 500 Antarctic fur seal pups for future demographic studies.
Measure metabolic rates and thermo-neutral zones of pups and juvenile Antarctic fur seals using a metabolic chamber.
Collect teeth from selected Antarctic fur seals for age determination and other demographic studies.
Deploy a weather station for continuous recording of wind speed, wind direction, ambient temperature, humidity, and barometric pressure.

DESCRIPTION OF OPERATIONS

Shipboard Research:

For the fifth consecutive year, the cruise was conducted aboard the chartered Russian research vessel R/V *Yuzhmorgeologiya*.

Itinerary

Leg I:	Depart Punta Arenas	08 January 2000
	Calibrate in Leith Harbor, South Georgia	12 January
	CCAMLR 2000 survey	13 January-04 February
	Resupply Cape Shirreff camp	05 February
	Cape Shirreff survey	06-10 February
	Recover personnel from Copacabana camp	12 February
	Arrive Punta Arenas	15 February
Leg II:	Depart Punta Arenas	18 February
	Transfer personnel and supplies at Cape Shirreff	21 February
	Calibrate at Cape Shirreff	21 February
	Large-area survey (Survey D)	22 February-07 March
	Calibrate at Admiralty Bay	07 March
	Close Copacabana camp	08 March
	Close Cape Shirreff	09 March
	Arrive Punta Arenas	12 March

Leg I.

1. The R/V *Yuzhmorgeologiya* departed Punta Arenas, Chile en route to South Georgia.
2. The acoustic transducers were calibrated in Leith Harbor, South Georgia. The transducers, operating at 38 kilohertz (kHz), 120kHz, and 200kHz, were hull-mounted and down-looking. Standard spheres were positioned beneath the transducers via outriggers and monofilament line. The beam patterns were mapped, and system gains were determined. In addition, a specially-outfitted Zodiac was launched and acoustic sensors, navigation systems, and safety equipment were tested in preparation for a survey off Cape Shirreff later in the cruise.
3. A multi-national, multi-ship survey of Antarctic krill and whales organized by CCAMLR and the International Whaling Commission (IWC), known as the CCAMLR 2000 survey, was conducted across the Scotia Sea (Figure 2). Other vessels participating in the survey were the R/V *James Clarke Ross* (United Kingdom), the R/V *Kaiyo Maru* (Japan), and the R/V *Atlantida* (Russia). Survey components included acoustic mapping of zooplankton, direct sampling of zooplankton, Antarctic krill demographics, and marine mammal and bird observations. Also, physical oceanography and phytoplankton observations were obtained.

Continuous environmental data were collected throughout Leg I, which included measurements of ship's position, sea surface temperature and salinity, fluorescence, air temperature, barometric pressure, relative humidity, wind speed, and wind direction.

5. The ship visited the Cape Shirreff field camp to deliver provisions and supplies.

A high-resolution survey for krill and oceanographic conditions was conducted in the vicinity of Cape Shirreff (Figure 3). A specially-outfitted Zodiac conducted a series of acoustic transects, CTD deployments and underwater video observations within 15 miles of Cape Shirreff. The ship complemented these measurements on a coarser grid further offshore, deploying an Isaacs-Kidd Midwater Trawl (IKMT).

The ship rendezvoused with the R/V *James Clark Ross* near Deception Island; zooplankton samples collected during the CCAMLR 2000 survey were passed to British Antarctic Survey colleagues for permanent archiving in Cambridge.

The ship visited the Copacabana field camp at Admiralty Bay, King George Island to retrieve four personnel.

Leg II.

1. The R/V *Yuzhmorgeologiya* departed Punta Arenas, Chile via the eastern end of the Strait of Magellan and arrived at Cape Shirreff to deliver supplies and personnel to the field camp.

The acoustic transducers were calibrated while the ship was at anchor near Cape Shirreff.

3. A large-area survey of 97 Conductivity-Temperature-Depth (CTD) and net sampling stations, separated by acoustic transects, was conducted in the vicinity of Elephant, Clarence, King George, and Livingston Islands (Survey D, Figure 4). Stations are located in three areas: stations to the west of Livingston and King George Islands are designated the “West area,” those to the south of King George Island are designated the “South area,” and those around Elephant Island are called the “Elephant Island area”. Acoustic transects were conducted at 10 knots, using hull-mounted 38kHz, 120kHz, and 200kHz down-looking transducers. Operations at each station included: (a) vertical profiles of temperature, salinity, and oxygen, and measurements of chlorophyll at 5 meters depth; and (b) deployment of an IKMT to obtain samples of zooplankton and micronekton.

Optical oceanographic measurements were conducted, which included weekly SeaWiFS satellite images of surface chlorophyll distributions and *in-situ* light spectra profiles.

As on Leg I, continuous environmental data were collected throughout the second leg.

Following the completion of Survey D, the acoustic transducers were calibrated in Ezcurra Inlet, Admiralty Bay, and King George Island. The Copacabana field camp was closed and field personnel were retrieved. The ship then transited to Cape Shirreff to embark personnel and close the field camp.

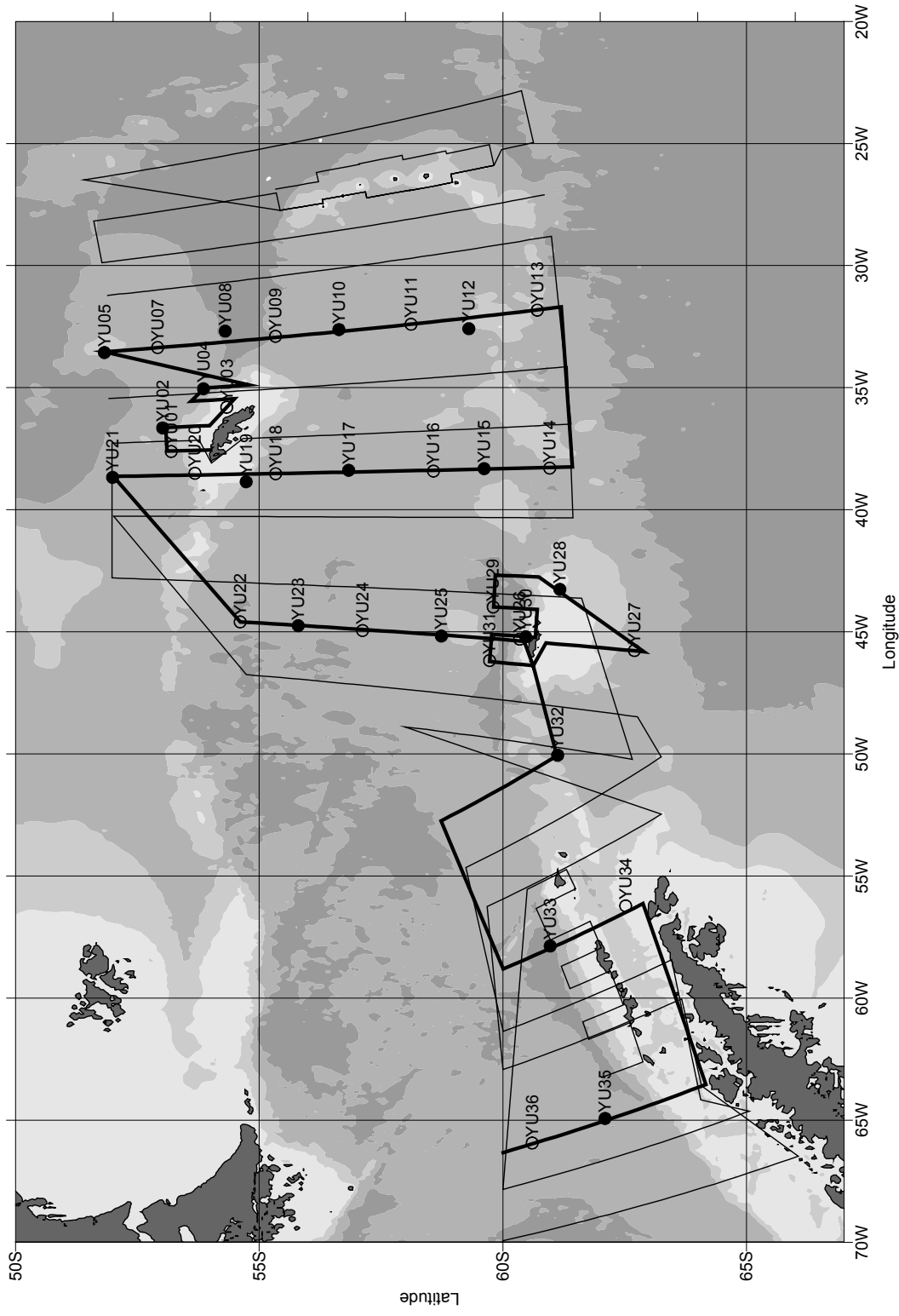


Figure 2. CCAMLR 2000 Survey. Heavy line describes trackline of R/V *Yuzhmorgeologiya*. Open circles represent day-time stations; closed circles represent night-time stations. Light lines represent tracklines of other ships involved in the CCAMLR 2000 Survey (British R/V *James Clark Ross*, Japanese R/V *Kaiyo Maru*, and Russian R/V *Atlantida*). See Report of Bo Workshop, SC-CAMLR-XIX, 2000, CCAMLR, Hobart, Australia for more details. Depth shading is 0-500m, 500-2000 m, 2000-4000m, and greater than 4000 m.

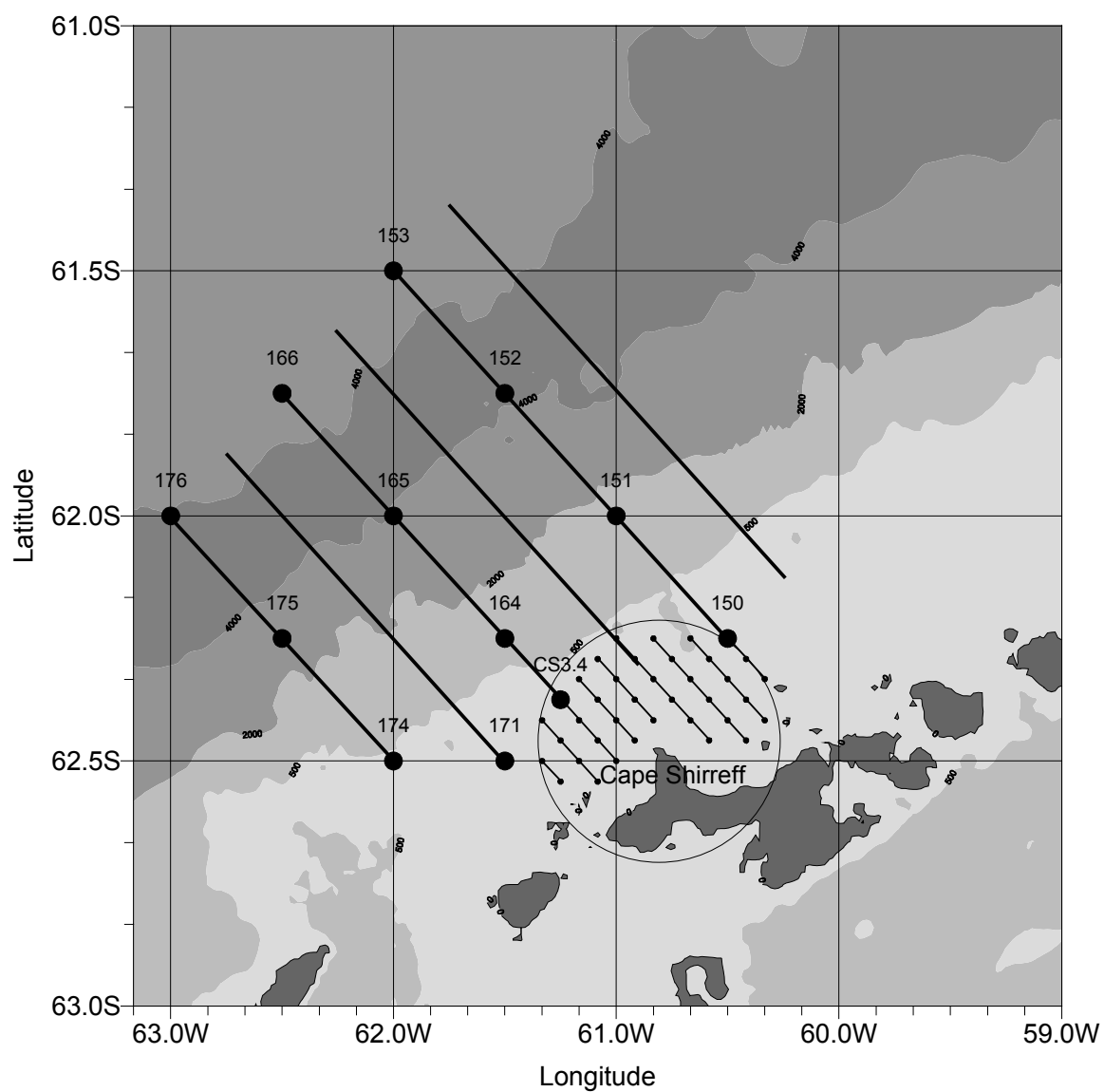


Figure 3. Cape Shirreff inshore survey area. Depth shading is 0-500m, 500-2000m, 2000-4000m and greater than 4000m.

Land-based Research:

Cape Shirreff

1. A four-person field team (M. Goebel, T. Carten, M. Rutishauser, and M. Taft) arrived at Cape Shirreff, Livingston Island, on 31 October 1999 via the R/V *Lawrence M. Gould*. Equipment and provisions were also transferred from the R/V *Lawrence M. Gould* to Cape Shirreff.
2. Two additional personnel (R. Holt and B. Parker), along with supplies and equipment, arrived at Cape Shirreff via the R/V *Lawrence M. Gould* on 22 December 1999. D. Costa arrived at Cape Shirreff via the Aurora Expeditions tour ship, M/V *Prof. Molchanov* on 29 January 2000. Two personnel (D. Demer and A. Jenkins) from the R/V *Yuzhmorgeologiya* visited Cape Shirreff from 5 to 10 February 2000 while they conducted an inshore acoustic survey. N. Gales arrived via the R/V *Yuzhmorgeologiya* on 21 February 2000.
3. Camp maintenance at Cape Shirreff included painting of interior and exterior of camp structures, interior construction of the emergency shelter/bird observation blind, construction of a deck on the storeroom and main hut, and upgrades to electrical fixtures.
4. The annual census of active gentoo penguin nests was conducted on 26 November 1999, and a similar census of chinstrap penguin nests was completed on 30 November 1999. Reproductive success was studied by following a sample of 100 chinstrap penguin pairs and 50 gentoo penguin pairs from egg laying to crèche formation.
5. Radio transmitters were attached to 18 chinstrap penguins on 2 and 3 January 2000; these instruments were used to determine foraging trip duration during the chick-rearing phase. All data were received and stored by a remote field computer set up at the bird observation blind.

Five satellite-linked transmitters were deployed on adult chinstrap penguins on 8 January to determine foraging location.
7. Diet studies of chinstrap and gentoo penguins during the chick-rearing phase were initiated on 4 January 2000 and continued through 8 February 2000. Chinstrap and gentoo adult penguins were captured upon returning from foraging trips, and their stomach contents were removed by lavaging.
8. A count of all gentoo penguin chicks was conducted on 4 February 2000, and for chinstrap penguin chicks on 8 February 2000. Fledging weights of chinstrap penguin chicks were collected 16-24 February 2000. Two hundred gentoo penguin chicks were also weighed on 10 February 2000.

9. One thousand chinstrap penguin chicks and 200 gentoo penguin chicks were banded for future demographic studies.
10. Reproductive studies of brown skuas and kelp gulls were conducted around the Cape.
11. Time-depth recorders (TDRs) were deployed on chinstrap and gentoo penguins for 10-12 day foraging periods to study diving behavior.
12. Antarctic fur seal pups and female fur seals were counted at four main breeding beaches every other day from 2 November 1999 through 9 January 2000.
13. Attendance behavior of female Antarctic fur seals was measured using radio transmitters. Twenty-four lactating female seals were instrumented 5-12 December 1999, and their pups were captured, weighed, and measured.
14. U.S. researchers assisted Chilean scientists in collecting data on Antarctic fur seal pup growth. Measurements of mass, length, and girth for 100 pups were begun on 16 December 1999 and continued every two weeks until 5 March 2000.
15. Information on Antarctic fur seal diet was collected using three different methods: scat collection, enemas of captured animals, and fatty-acid signature analyses of milk.
16. Antarctic fur seals were instrumented with TDRs for diving behavior studies.
17. Antarctic fur seal females were instrumented with ARGOS satellite-linked transmitters for studies of foraging locations and energetics. Some of these fur seals also received injections of doubly-labeled water for measurements of metabolic rate, water flux, and energy expended.
18. Five hundred Antarctic fur seal pups were tagged at Cape Shirreff by U.S. and Chilean researchers for demography studies.
19. Weather data recorders were set up at Cape Shirreff for wind speed, wind direction, barometric pressure, temperature, humidity, and rainfall.
20. One team member (T. Carten) left Cape Shirreff via a Chilean Navy vessel on 23 February 2000. Two personnel (D. Costa and N. Gales) were retrieved from Cape Shirreff via the M/V *Prof. Molchanov* on 24 February 2000.
21. The Cape Shirreff field camp was closed for the season on 9 March 2000; all personnel (M. Goebel, M. Rutishauser, M. Taft, R. Holt, and B. Parker), garbage, and equipment were retrieved by the R/V *Yuzhmorgeologiya*.

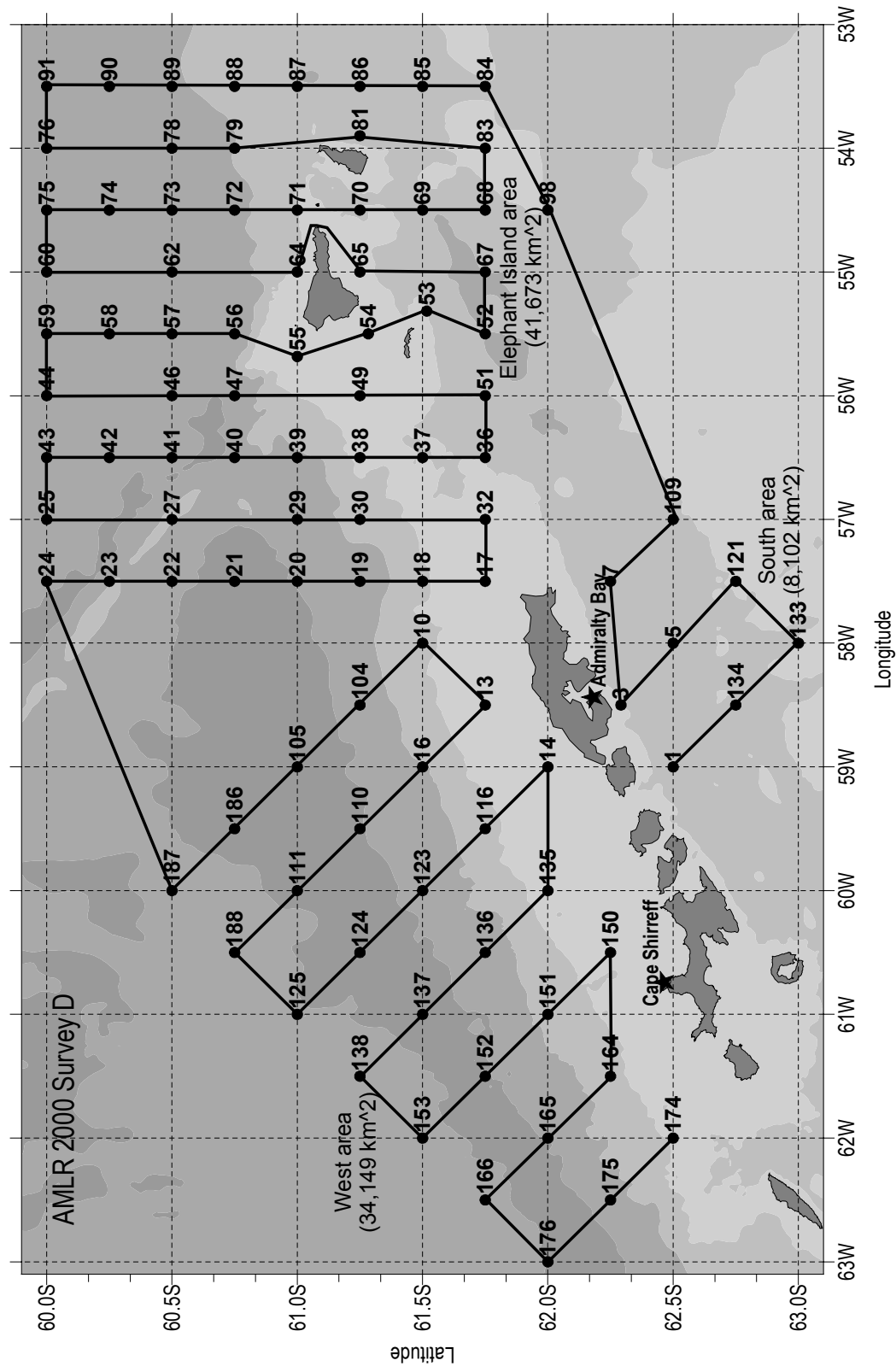


Figure 4. The large-area survey for AMLR 2000 (Survey D) in the vicinity of Elephant, Clarence, King George and Livingston Islands. Stations located to the west of Livingston and King George Islands are designated the “West area”, those to the south of King George Island are designated the “South area” and those around Elephant Island are designated the “Elephant Island area”. Depth shading is 0-500m, 500-2000m, 2000-4000m and greater than 4000m.

SCIENTIFIC PERSONNEL

Cruise Leader:

Roger P. Hewitt, Southwest Fisheries Science Center (Legs I and II)

Physical Oceanography:

David A. Demer, Southwest Fisheries Science Center (Leg I)

Roger P. Hewitt, Southwest Fisheries Science Center (Leg II)

Pierre Malan, Sea Fisheries Research Institute (Leg I)

Rob Rowley, Moss Landing Marine Laboratories (Legs I and II)

Phytoplankton:

Christopher D. Hewes, Scripps Institution of Oceanography (Leg II)

John Wieland, Scripps Institution of Oceanography (Leg II)

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Bioacoustic Survey:

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David A. Demer, Southwest Fisheries Science Center (Leg I)

Dale Roberts, NMFS, Tiburon Laboratory (Legs I and II)

Jennifer Emery, University of California at Santa Cruz (Leg II)

Krill and Zooplankton Sampling:

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Rob Rowley, Moss Landing Marine Laboratories (Legs I and II)

Jenna Borberg, Moss Landing Marine Laboratories (Legs I and II)

Kim Dietrich (Leg II)

Nancy Gong, University of California at Santa Cruz (Leg II)

Adam Jenkins, Southwest Fisheries Science Center (Legs I and II)

Pierre Malan, Dept of Environmental Affairs, South Africa (Leg I)

Dorothee Stübing, Universität Bremen (Leg II)

Fur Seal Energetics Studies:

Alison R. Banks, University of California at Santa Cruz (Legs I and II)

Krill Genetic Studies:

Bo Bergstrom, Swedish Academy of Sciences (Leg I)

IWC Whale Survey:

Steve Reilly, Southwest Fisheries Science Center (Leg I)

Deborah Thiele, Deakin University, Australia (Leg I)
Paula Olson, Southwest Fisheries Science Center (Leg I)
James Cotton, Southwest Fisheries Science Center (Leg I)
Simon Berrow, British Antarctic Survey (Leg I)
Amy Williams, Northeast Fisheries Science Center (Leg I)

Film Maker:

Judy Rhee, NYU (Leg I)

Cape Shirreff Personnel:

Michael E. Goebel, Southwest Fisheries Science Center (10/31/99 to 3/9/00)
Terence Carten (10/31/99 to 2/23/00)
Daniel P. Costa, University of California at Santa Cruz (1/29/00 to 2/24/00)
Nick Gales, Dept. of Conservation and Land Management, Australia (2/21/00 to 2/24/00)
Rennie S. Holt, Southwest Fisheries Science Center (12/22/99 to 3/9/00)
Brian Parker, Southwest Fisheries Science Center (12/22/99 to 3/9/00)
Matthew R. Rutishauser, University of California at Santa Cruz (10/31/99 to 3/9/00)
Michael Taft (10/31/99 to 3/9/00)